Multipurpose Hydrogen Test-Bed

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The development of high-energy cryogenic upper stages is essential for the efficient delivery of large payloads to various destinations envisioned in future programs. A key element in such upper stages is cryogenic fluid management (CFM) advanced development/technology. Due to the cost of and limited opportunities for orbital experiments, ground testing must be employed to the fullest extent possible. Therefore, a system level test-bed termed the multipurpose hydrogen test-bed (MHTB), which is representative (in size and shape) of a fully integrated space transportation vehicle liquid hydrogen propellant tank, has been established. The MHTB is currently being implemented to evaluate CFM technology in support of the solar thermal propulsion.

The MHTB tank is ASME coded, is 10 ft in diameter by 10 ft long, has a 639 ft^3 capacity, and is made from 5083 aluminum. The tank design is based on enabling accommodation of various CFM concepts as updated or alternate versions become available. Major accommodations include: a 24-in diameter manhole; 1-in diameter pressurization and 2-in diameter vent ports; a 1-in diameter fill/drain line (through tank top); the Rockwell pressure control system enclosure interface provisions; a 3-in diameter drain at the tank bottom for future growth; a liquid-level capacitance probe; two liquid temperature rakes; wall temperature measurements at selected locations; ullage pressure sensors; pressure control/relief safety provisions; internal mounting brackets for future equipment and structural “hard points” for temporary scaffolding, ladder, etc; and low heat leak structural supports.

FIGURE 36.—Assembled multipurpose hydrogen test-bed.

Upper stage studies have often baselined the foam/multilayer insulation (FMLI) combination concept; however, hardware experience with the concept is minimal and it was therefore selected for the MHTB. The foam element is designed to protect against ground hold/ascent flight environments, and to enable a dry nitrogen purge as opposed to the more complex/heavy helium purge subsystem normally required with MLI in cryogenic applications. The MLI provides protection in the vacuum environment of space and is designed for an on-orbit storage period of 45 days. The foam component consists of an isofoam SS–1171 layer, with an average thickness of 1.3 in, bonded to the tank wall.

The MLI consists of a double aluminized mylar (DAM) MLI blanket with an average layer density of approximately 25 layers/in, which is composed of 45 radiation shields

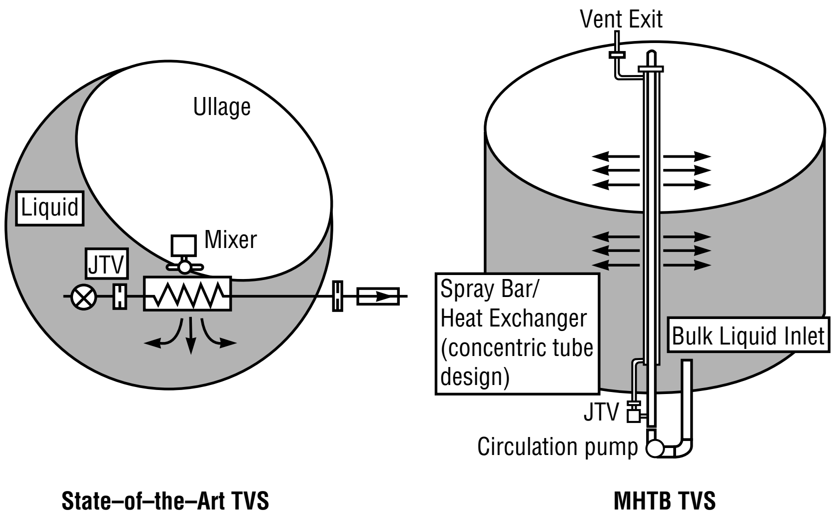

Figure 37.—MHTB TVS concept—spray bar with external active components.

with coarse Dacron net spacer material. Unique features of the MLI concept include a variable density MLI (reduces weight and radiation losses) and fewer but larger perforations for venting during ascent to orbit. The tank barrel section MLI was installed utilizing a commercially established roll-wrap process. It is estimated that the roll-wrap approach will save about 2,400 man-hours, compared with the standard blanket installation process, on a 10-ft diameter LO_2/LH_2 tank set. The process reduces heat leak due to the lack of seams and is less susceptible to structural damage during ascent flight.

Thermal performance testing was conducted during three test series conducted between September 1995 and May 1996. Preliminary results indicate that the orbital boiloff was reduced by 40 to 50 percent compared with the best MLI previously tested, i.e., boiloff losses were about 0.11 percent per day with a warm boundary temperature of 520 °R. The foam evidently performed as expected but further evaluation is required to quantify its reusability characteristics.

Thrusters have traditionally been used to settle the liquid prior to orbital tank venting with penalties in performance and operational complexity (Centaur and Saturn/S-IVB). The thermodynamic vent system (TVS) concept enables venting without resettling, but its utilization is constrained by a lack of on-orbit experience. The TVS concept selected for the MHTB differs from those previously tested in that the active components (a Joule-Thompson (J-T) expansion valve, subsystem pump, and isolation valve) are located external to the tank, as opposed to inside the tank, in a stainless steel cylindrical enclosure which is attached to the bottom of the MHTB tank. Such an approach enables modification or changeout of TVS components without entering the tank. In the mixing mode, fluid is withdrawn from the tank by the pump and flows back into the tank through a spray bar positioned along (or near) the tank longitudinal axis. The fluid expelled radially into the tank through the spray bar forces circulation and mixing of the tank contents regardless of liquid and ullage position, assuring destratification and minimum pressure rise rate. When pressure relief eventually becomes necessary, a portion of the circulated liquid is passed through the J-T valve (expanded to a lower temperature and pressure) then through the heat exchanger element of the spray bar, and finally is vented to space. The vented fluid thereby cools the fluid circulated through the mixing element of the spray bar and removes thermal energy from the bulk liquid. In an orbital propellant transfer scenario the spray-bar concept can also be utilized to assist tank refill. By filling through the spray bar/heat exchanger the inflowing fluid can be cooled and used to mix the tank contents, thereby assuring the accomplishment of a “no-vent fill” process. The zero-g vent subsystem testing was completed in October 1996 and the data evaluation is in progress.

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Biographical Sketch: Leon Hastings, currently assigned to the MSFC Propulsion Laboratory, received his B.S. in mechanical engineering and an M.S. in engineering science. Assignments at MSFC since 1961 have centered on heat transfer, fluid mechanics, and thermodynamics, and he has over 15 years of specialized experience in low-gravity fluid management and heat transfer. He has often served on agency-level committees to assist in formulating plans/policies for low-gravity propellant management research and technology.